



REMR Technical Note CO-SE-1.5

Coastal Structure Underwater Inspection Technologies

Purpose

To introduce multibeam sonar technology for use in performing high-resolution, quantitative surveys of coastal structures.

Background

Most damage to coastal structures, especially rubble-mound breakwaters and jetties, occurs to the underwater portion of the structure. Underwater damage such as scour, settlement, and scattering and breakage of armor units is not often exhibited on the surface, and damage can progress until a major structural collapse occurs. Detection of underwater damage and deterioration is cost effective for coastal engineers in terms of planning for structure repairs and rehabilitation and for management of coastal structures over their lifetimes.

Diver inspections provide some information about the condition of underwater structures, but these surveys are often difficult and risky, hampered by the normal occurrence of waves, currents, and limited visibility around the structure. The information obtained from diver surveys is subjective, and spatial detail is sparse. Additionally, results from side-scan sonars (SSS), a viable tool for structural surveys (Kucharski and Clausner 1990), are semi-quantitative and often distorted because of energetic wave and current conditions around the structure.

In response to a need for objective, detailed, and quantitative definition of the underwater shape of coastal structures, initial REMR research conducted at the U.S. Army Engineer Waterways Experiment Station (WES) focused on hardware identification, evaluation, and prototype design. This research resulted in development of the Coastal Structure Acoustic Raster Scanner (CSARS) system. Since 1991, REMR investigations in this problem area have focused on developing hardware and software tools to inspect underwater portions of irregular, rubble-mound coastal structures.

The CSARS system is a remote, bottom-deployed system consisting of a tripod containing a pointable 300-kHz acoustic transducer unit with driving motors and sensors (Figure 1). The CSARS tripod is cabled to an operator-controlled shipboard computer system that allows for real-time graphical display and onsite data postprocessing. The device has performed successfully in field

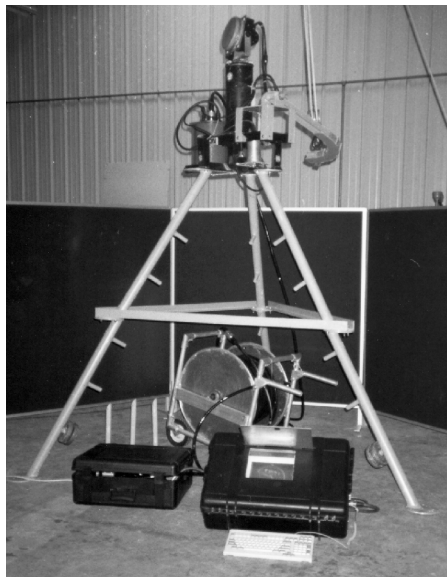


Figure 1. CSARS system

trials at several coastal sites. A more detailed description of the CSARS system and its development is found in Lott, Howell, and Higley (1990) and Lott (1991).

In addition to the development of CSARS, newly emerging technology for monitoring coastal structures has also been investigated during the REMR Research Program, resulting in the discovery of high-resolution multibeam sonar systems in the commercial market. State-of-the-art, high-resolution multibeam sonar systems have evolved from technological advances on several fronts, including the development of Differential Global Positioning System (DGPs); advanced computer hardware and

software capable of collecting, storing, and processing dense data sets; and improved motion compensators and roll, heave, and pitch sensors. The combination of advanced positioning and motion sensors with new sonar technology has resulted in state-of-the-art optimal swath systems ideally suited for shallow-water survey applications such as coastal structure condition assessment surveys. These commercially available systems proved superior to the still-prototype CSARS system, and focus was redirected towards investigation of multibeam sonar system applications for inspection and surveying of coastal structures. For this investigation, the SeaBat 9001 (Figure 2) developed by RESON, Inc., of Goleta, CA, was selected for testing above other multibeam systems because it was more compact and less expensive.

SeaBat 9001 System

The SeaBat 9001 is a portable, downward and side-looking single-transducer multibeam sonar system. The main component of the SeaBat system is an acoustic sonar head operating at 455 kHz that transmits 60 sonar beams spaced at 1.5° in a fan pattern to provide a maximum sounding swath of 90° . This configuration enables swath coverage of twice the water depth. The sonar head is typically vertically deployed from a fixed mount off the side of the small vessel and is cabled to an external computer or data logger that controls display, data processing, and output in real time



Figure 2. SeaBat head mounted on boat



Figure 3. SeaBat sonar head being deployed

(Figure 3). A pointer device such as a trackball or joystick is used for operational control of the sonar head. The sonar head is tiltable for mapping steeply sloped or vertical structures to the edge of the water. The SeaBat mounting and beam configurations are illustrated in Figure 4.

The SeaBat 9001 system can take 60 simultaneous soundings at a rate of over 15 profiles per second. SeaBat depth precision in ideal conditions is 0.13 ft (0.04 m) below the sensor and 0.3 ft (0.09 m) at the outermost beams at vessel speeds up to 12 knots (6.17 m/sec) (Headquarters, Department of the Army 1994). SeaBat images can be viewed in real time and videotaped for data postprocessing quality checks.

In addition to the SeaBat data, simultaneous measurements of vessel position, heading, and motion (heave, pitch, and roll) are required for postprocessing geometric data corrections. Bathymetric data corrections are necessary to produce accurate measurements of true depths referenced to vertical and horizontal datum for individual beams. Computer time tags of all data are also necessary. An overall system configuration is provided in Figure 5.

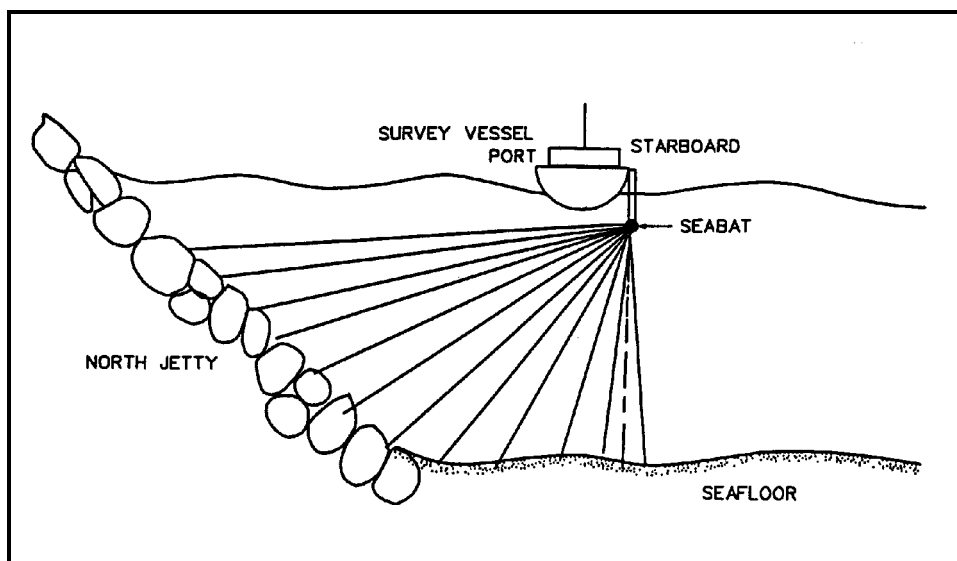


Figure 4. SeaBat mounting and beam configuration on steeply sloping structure (Hughes et al. 1995)

Once geometrically corrected and processed, the SeaBat provides a dense data set of xyz coordinates of point data (spot) elevations. From this data set, a three-dimensional mesh surface connecting the spot elevations (called digital elevation models or DEMs, and also called digital terrain models or DTMs), can be created in addition to specified cross sections and contour maps. A DEM from the Yaquina Bay North Jetty Survey (see Table 1) is provided as an example in Figure 6.

SeaBat Field Demonstrations and Trials

In 1993 and 1994, information about the potential uses of the SeaBat system was disseminated by the WES team throughout the hydrographic survey community. As a result, several U.S. Army Corps of Engineers (USACE) Districts and hydrographic survey contractors sponsored SeaBat system demonstrations for varied applications. Table 1 lists those demonstrations attended by WES personnel. Demonstration attendees included personnel from other USACE Districts, academia, and private hydrographic surveyors.

Development of the SeaBat system and its application to coastal structure surveys continued to evolve as the system was demonstrated and tested. Equipment improvements included innovative mounts and data collection hardware and software. Data collection procedures were tested, data density requirements were explored, and processing techniques were refined.

Summary

The demonstrations and success of the field trials have proved that the commercially available SeaBat multibeam system can be applied for use in coastal structure underwater surveys. Hydrographic surveying using state-of-the-art multibeam swath systems provides nearly 100-percent bathymetric coverage of the structure up to the edge of the water, resulting in a detailed and quantitative definition of the underwater shape of coastal structures. The SeaBat swath systems and others like it are fast becoming standard equipment for shallow-water surveying applications. Several USACE Districts have purchased multibeam systems or are including multibeam sonars in specifications for private survey contractors. Additional details of the SeaBat 9001 and description of other multibeam swath systems employed on USACE hydrographic survey contracts are provided in Engineer Manual 1110-2-1003, "Hydrographic Surveying" (Headquarters, Department of the Army 1994).

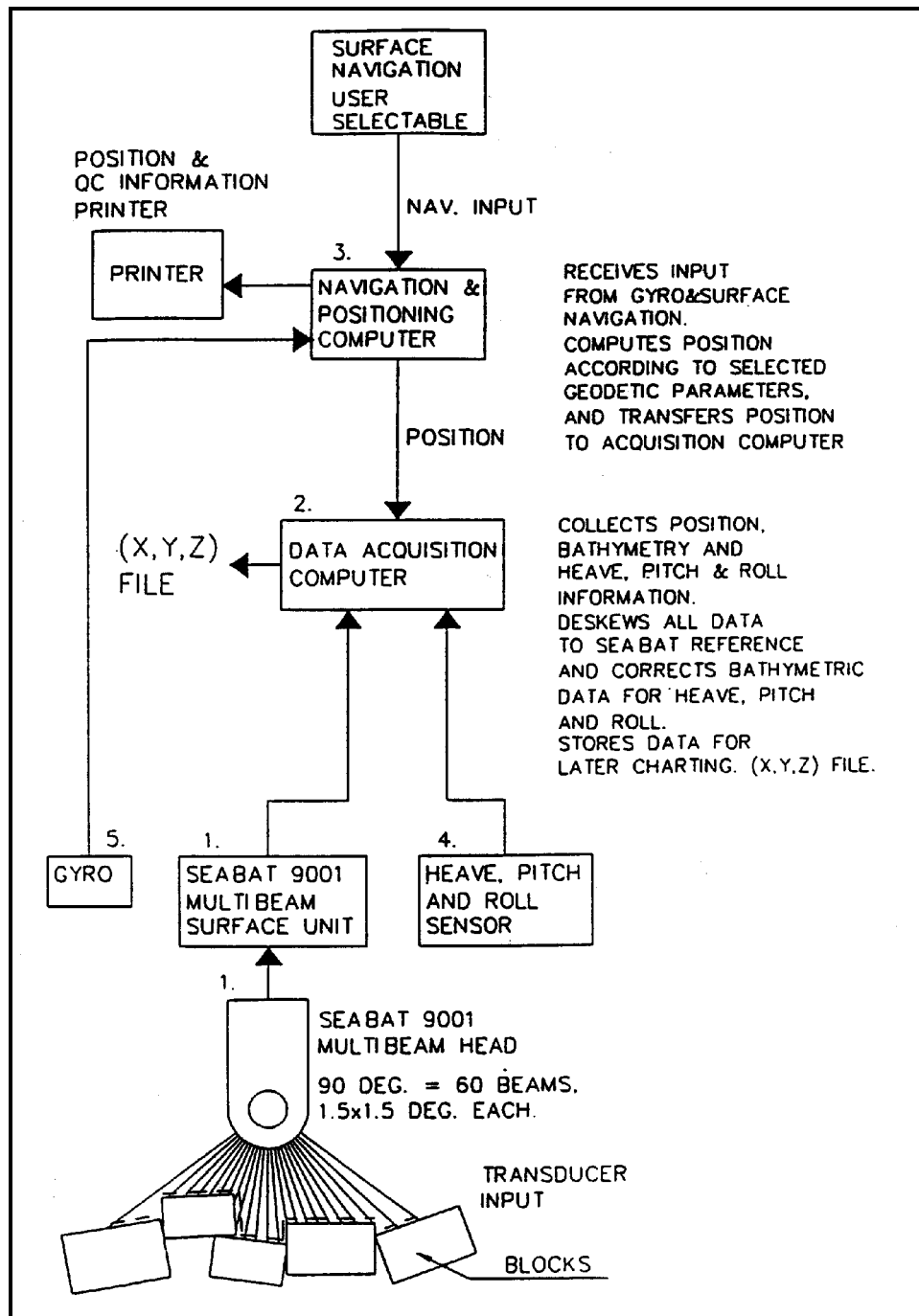


Figure 5. SeaBat system configuration (Headquarters, Department of the Army 1994)

Table 1 SeaBat Demonstrations and Field Trials		
Sponsor	Location	Application
Demonstrations		
USACE District, Los Angeles	Los Angeles, CA	San Pedro Breakwater
USACE District, Memphis	Memphis, TN	Bridge pier scour on Mississippi River
Oceaneering, Solus Schall Division (Upper Marlboro, MD)	St. Louis, MO	Missouri River Bridge pier scour (after Flood of 1993)
EMC, Inc., (Greenwood, MS)	Crescent City, CA	Harbor entrance survey (dolos inspection)
Ocean Surveys, Inc. (Old Saybrook, CT)	Old Saybrook, CT	Connecticut River entrance on Long Island Sound
WES	Duck, NC	CHL Field Research Facility
Field Trials		
USACE District, Buffalo, and WES	Cleveland, OH	Cuyahoga River retaining structure reconnaissance survey
USACE District, Los Angeles, and WES	Los Angeles, CA	Los Angeles (San Pedro) Harbor and Long Beach breakwaters
USACE District, New York	Long Island, NY	Shinnecock and Moriches Inlets
USACE District, Philadelphia, PA	Rehoboth, DE	Indian River Inlet
WES and USACE District, Portland	Newport, OR	Yaquina Bay north jetty survey

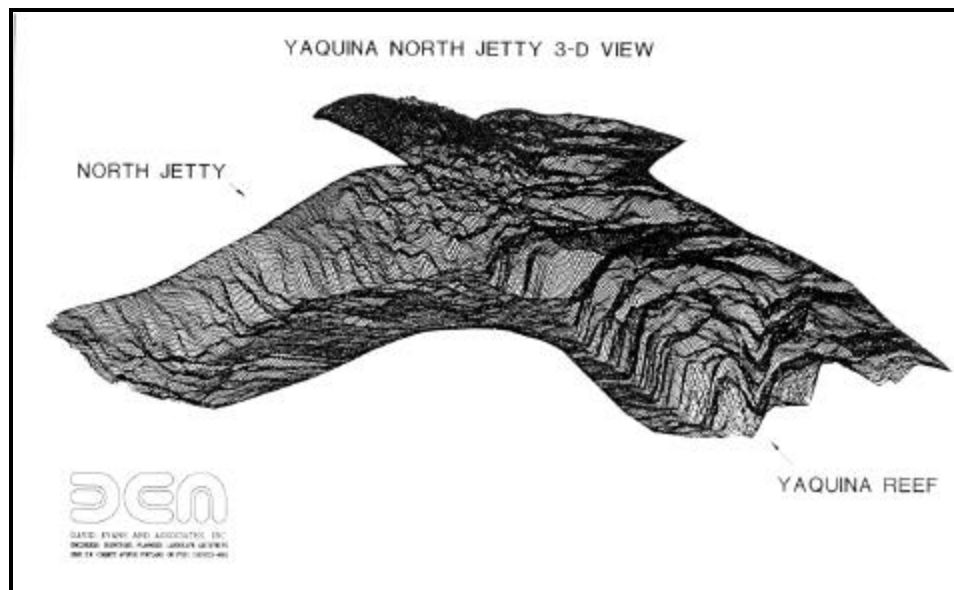


Figure 6. DEM of Yaquina Bay north jetty and Yaquina Reef below-water bathymetry (Hughes et al. 1995)

References

- Headquarters, Department of the Army. (1994). "Hydrographic surveying," Engineer Manual 1110-2-1003, U.S. Army Corps of Engineers, Washington, D.C.
- Hughes, S.A., Prickett, T.L., Tubman, M.W., and Corson, W.D. (1995). "Monitoring of the Yaquina Bay entrance north jetty at Newport, Oregon; summary and result," Technical Report CERC-95-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Kucharski, W.M., and Clausner, J.E. (1990). "Underwater inspection of coastal structures using commercially available sonars," Technical Report REMR-CO-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lott, J.W. (1991). "Coastal Structure Acoustic Raster Scanner (CSARS) system for underwater inspection," *The REMR Bulletin* 8 (3), U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lott, J.W. Howell, G.L., and Higley, P.D. (1990). "Development of the Coastal Structure Acoustic Raster Scanner," *Proceedings, U.S. Army Corps of Engineers Seventh Remote Sensing Symposium*.